Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
5GAA Petition for Waiver to Allow	)	
Deployment of Cellular	)	
Vehicle-To-Everything (C-V2X)	)	GN Docket No.: 18-357
Technology in the 5.9 GHz Band	)	
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COMMENTS OF NXP USA, INC.

Jennifer Wuamett
Executive Vice President and General Counsel
NXP Semiconductors

Lars Reger
Senior Vice President, Chief Technology Officer
NXP Semiconductors

Peter Esser
Head of Government Affairs
NXP Semiconductors

NXP USA, Inc.
6501 William Cannon Drive West
Austin, Texas 78735
Direct: +1.202.621.1831
Email: peter.esser@nxp.com
www.nxp.com

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Summary

NXP Semiconductors, a combination of the former semiconductor divisions of Philips and Motorola, is a semiconductor company with significant operations in the United States, Europe and Asia, built on more than 60 years of combined experience and expertise. NXP Semiconductors is the world's largest semiconductor supplier to the automotive industry and is the global leader in automotive chipsets that enable Intelligent Traffic Systems ("ITS") through Dedicated Short Range Communications ("DSRC") technology.

With DSRC-enabled applications at the front edge of deployment and a growing number of U.S. launch commitments from automotive giants such as GM and Toyota, NXP believes that the introduction of new and relatively untested cellular-based products into the 5.9 GHz band would create substantial uncertainty and cause significant delay of DSRC-based product launches due to clear interference and interoperability issues. The LTE C-V2X technology for which 5GAA seeks a waiver is not superior to DSRC technology and it is not the technology of the future. Moreover, C-V2X's path to 5G is unclear and the manner in which it might address backward compatibility and interoperability issues is uncertain.

C-V2X technology is simply too immature for the Commission to give serious consideration to revisiting or revising its well-reasoned decision to adopt a single-standard – DSRC – for ITS. However, given the importance of ITS to public safety and traffic management, the Commission may reasonably decide to commence a notice of inquiry to explore how 5G technologies may be developed, tested and deployed in a complementary manner that does not interfere with or detract from the benefits of utilizing DSRC as the single standard for short range V2X communications. Such a proceeding or a follow-on rulemaking could also explore whether a portion of spectrum already allocated to 5G might

be used for new ITS applications. Consistent with the goal of ensuring ITS operates in the U.S. using a universal standard that allows all ITS-equipped vehicles and infrastructure to communicate reliably and so that deployment and development of new DSRC applications continues as rapidly as possible, the Commission should make clear that it has no intention of reallocating spectrum in the 5.9 GHz band for any purpose.

Accordingly, NXP opposes 5GAA's Petition for Waiver to Allow Deployment of Cellular Vehicle-to-Everything ("C-V2X") Technology in the 5.9 GHz Band. Granting such a waiver would have a detrimental impact on current and future V2X deployment using DSRC technology, and it would jeopardize public safety and undermine the purposes of the Commission's single-standard 5.9 GHz rules.[1]

As explained more fully herein, The Commission should deny 5GAA's petition for the following reasons:

- **Grant of the requested waiver will jeopardize public safety by introducing interference and interoperability risks that will compromise traffic safety and impair DSRC-based V2X traffic safety applications and technology.**
- **Grant of the requested waiver will interfere with current and impede planned DSRC deployments, while limiting the spectrum available for future DSRC-based V2X applications.**
- **5GAA's C-V2X performance and cost claims do not support a waiver.**

[1] *See Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850-5.925 GHz Band (5.9 GHz Band)*, et al., Report and Order, 19 FCC Rcd 2458 (2003) ("Report and Order"), paras. 11-22.

For these reasons, as explained more fully herein, NXP respectfully urges the Commission to deny the petition for a waiver to allow deployment of C-V2X technology in the 5.9 GHz band.

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COMMENTS OF NXP USA, INC.

I. INTRODUCTION

NXP USA, Inc. ("NXP") respectfully submits these comments in opposition to the 5GAA Petition for Waiver to Allow Deployment of Intelligent Transport System Cellular Vehicle to Everything (C-V2X) Technology in the 5.9 GHz band.[2]

NXP Semiconductors, a combination of the former semiconductor divisions of Philips and Motorola, is a semiconductor company with significant operations in the United States, Europe and Asia, built on more than 60 years of combined experience and expertise. NXP Semiconductors is the world's largest semiconductor supplier to the automotive industry and is the global leader in automotive chipsets that enable Intelligent Traffic Systems ("ITS") through Dedicated Short Range Communications ("DSRC") technology. With DSRC-enabled applications at the front edge of deployment and a growing number of

[2] *See* 5GAA Petition for Waiver to Allow Deployment of Intelligent Transportation System Cellular Vehicle to Everything (C-V2X) Technology, Docket No. 18-357 (filed Nov. 21, 2018) ("5GAA Petition"). *See also Office of Engineering and Technology and Wireless Telecommunications Bureau Extend Comment Cycle Deadlines on 5GAA Petition for Waiver to Allow Deployment of Cellular Vehicle-To-Everything (C-V2X) Technology in the 5.9 GHz Band*, Public Notice, DA 18-1310 (rel. Dec. 31, 2018).

launch commitments from automotive giants such as GM and Toyota, NXP is concerned that the introduction of new and untested LTE C-V2X products in the 5.9 GHz band would create substantial uncertainty and cause significant delay of DSRC-based product launches due to clear interference and interoperability issues.[3] The LTE C-V2X technology for which 5GAA seeks a waiver is not superior to DSRC technology and it is not the technology of the future. Moreover, C-V2X's path to 5G is unclear and the manner in which it might address backward compatibility and interoperability issues is uncertain.

C-V2X technology is simply too immature for the Commission to give serious consideration to revisiting or revising its well-reasoned decision to adopt a single-standard – DSRC – for ITS. However, given the importance of ITS to public safety and traffic management, the Commission may reasonably decide to commence a notice of inquiry to explore how 5G technologies may be developed, tested and deployed in a complementary manner that does not interfere with or detract from the benefits of utilizing DSRC as the single standard for short range V2X communications. Such a proceeding or a follow-on rulemaking also could also explore whether a portion of spectrum already allocated to 5G might be used for new ITS applications. Consistent with the goal of ensuring that ITS operates in the U.S. using a universal standard that allows all ITS-equipped vehicles and infrastructure to communicate reliably and so that deployment and development of new DSRC applications continues as rapidly as possible, the Commission should make clear that it has no intention of reallocating spectrum in the 5.9 GHz band for any purpose.

[3] NXP previously has submitted comments to the Commission opposing any change to the band allocated for ITS in North America and submitting that any new technology be backwards compatible and complementary to DSRC. Comments of NXP Semiconductors, ET Docket No. 13-49 at 1-2 (filed May 3, 2018).

II. THE COMMISSION SHOULD NOT WAIVE ITS REQUIREMENT FOR A SINGLE ITS STANDARD

Grant of the requested waiver would conflict with the Commission's finding that a single standard for ITS systems is appropriate.

As the Commission noted in the Report and Order adopting licensing and service rules for DSRC, the overall effectiveness of the national ITS would be drastically reduced without an interoperability standard that enables vehicles and infrastructure to communicate reliably regardless of location, equipment used or the licensee.[4] The C-V2X technology that is the subject of 5GAA's waiver request is not interoperable with the existing DSRC standard adopted by the Commission because the radio interfaces are simply incompatible. Vehicles equipped with the C-V2X technology will not be able to communicate with vehicles equipped with DSRC technology and vice versa. As a result, safety applications such as crash avoidance and intersection collision avoidance would not be available.[5] Allowing two separate technologies to operate in the dedicated ITS 5.9 GHz band that are unable to communicate frustrates the most fundamental purpose of the ITS: for vehicles to be able to communicate with each other with the goal of saving lives and preventing property damage by avoiding accidents.

By creating a second competing system for V2X communications, grant of the requested waiver would create a split market which will detract from the business case for V2X communications and actually inhibit nationwide ITS deployment. 5GAA's assertion

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[4] *See id.*, para. 14.

[5] National Highway Traffic Safety Administration, *Federal Motor Vehicle Safety Standards; V2V Communications*, Notice of Proposed Rulemaking, Docket No. NHTSA-2016-0126, available at https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/v2v_nprm_web_version.pdf.

that LTE-V2X would resolve current market inhibitions to V2X deployment is unrealistic: cost, functionality and car industry support would all be negatively affected by competition between C-V2X and DSRC.[6] With one exception, all commenters to the Commission's Notice of Proposed Rulemaking regarding the service rules for the DSRC in the 5.9 GHz band urged the Commission to adopt a single standard as a means to ensure that DSRC units would be interoperable nationwide.[7] Grant of the waiver request would be inconsistent with the Commission's decision to require interoperability through the use of a single standard and would be inconsistent with Congress's intent when it adopted legislation concerning DSRC.[8]

III. ALLOWING C-V2X TO OPERATE IN THE 5.9 GHz BAND WOULD CAUSE INTERFERENCE AND SPECTRUM CONTENTION

The Commission has concluded that it is paramount that communications in the 5.9 GHz band be protected from interference given the consequences to the traveling public should any one of the safety applications fail due to unacceptable error rates or delay.[9] The 5GAA petition, if granted, would cause interference to existing DSRC deployments and cause spectrum contention that would hinder the deployment of planned DSRC applications and the development of new DSRC applications.

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[6] *See* 5GAA Petition at 18-20.

[7] The lone exception, Qualcomm, is now a significant proponent of the proposed C-V2X technology.

[8] *See* Report and Order, para. 17.

[9] *See id.*, para. 15.

A. C-V2X in the 5 GHz Band Would Cause Interference with Existing DSRC Deployments

Because C-V2X works without any synchronization with DSRC systems, C-V2X applications have no awareness of the DSRC channel access timing and transmissions. As a result, collisions of each system's transmissions (i.e., simultaneous transmissions) will occur. Therefore, C-V2X deployment in one channel will cause a significant error rate on DSRC in the same channel. Such error rates would increase with additional C-V2X deployment. The 5GAA petition fully acknowledges that the potential for in-band disturbance will require both technologies to operate on exclusive channels.[10]

One major car manufacturer has announced deployment of DSRC systems on vehicles sold in the United States starting in 2021.[11] Another major car manufacturer has announced plans to extend current DSRC deployment across its entire top luxury brand vehicle line-up by 2023.[12] In its 2018 revision of its Automated Vehicle Policy, the U.S. Department of Transportation ("DOT") reported that throughout the nation there are over "70 active deployments of V2X communications utilizing the 5.9 GHz band. DOT currently estimates that by the end of 2018, over 18,000 vehicles will be deployed with aftermarket V2X communications devices and over 1,000 infrastructure V2X devices will be installed at the roadside. Furthermore, all seven channels in the 5.9 GHz band are actively utilized in

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[10] 5GAA Petition at 28, n.74.

[11] Toyota, "Toyota and Lexus to Launch Technology to Connect Vehicles and Infrastructure in the U.S. in 2021," Apr. 6, 2018, available at https://corporatenews.pressroom.toyota.com/releases/toyota+and+lexus+to+launch+technology+connect+vehicles+infrastructure+in+u+s+2021.htm ("Toyota and Lexus Announcement").

[12] General Motors, "Cadillac to Expand Super Cruise Across Entire Lineup," Jun. 6, 2018, available at https://media.gm.com/media/cn/en/gm/news.detail.html/content/Pages/news/cn/en/2018/June/0606_Cadillac-Lineup.html.

these deployments."[13] Grant of the requested waiver would pose an unacceptable risk that the C-V2X will interfere with DSRC communications on these and other future DSRC deployments in the dedicated 5.9 GHz Band.

B. C-V2X in the 5 GHz Band Would Cause Interference with Neighbor Channels

As explained above, because C-V2X works without any synchronization with DSRC systems, simultaneous transmissions will occur causing a significant error rate. Even if separate (but nearby) channels were assigned, part of the transmitted energy from C-V2X will interfere with the DSRC message reception, depending on the energies involved and the distances of receiver, transmitter and interferer. This would effectively reduce the sensitivity of DSRC systems, thereby reducing their effective range. In studies done in the European Car2Car Communication Consortium, it has been shown that this effect is significant. For example, a C-V2X station transmitting on a direct-adjacent channel at 30 meters distance can reduce the DSRC range from >600 meters to around 200 meters (line-of-sight situations). As a consequence of deploying C-V2X in the 5905-5925 MHz band, DSRC performance in the 5895-5905 MHz channel would be seriously reduced.

C. C-V2X in the 5 GHz band Would Hinder the Deployment of Planned DSRC Applications

The permanent loss of 20 MHz of spectrum available to DSRC would result in serious degradation of future DSRC deployments. Several studies—and use of the 70 MHz ITS spectrum as defined in the standard SAE J.2945—show future V2X communication to

[13] U.S. Department of Transportation, Preparing for the Future of Transportation: Automated Vehicles 3.0 at 14 (2018), available at https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf.

require the full bandwidth of the presently allocated 70 MHz with clearly defined purposes for each of the seven channels in the band.[14] [15] Without full access to each of the seven channels in the band, future DSRC deployment would be hobbled.

Moreover, 5GAA has announced plans to file a petition to claim even more spectrum, which could yield even more spectrum contention in the future.[16] Thus, grant of the 5GAA petition would result in two systems having access to only a part of the spectrum needed to operate effectively. The FCC should not hobble DSRC development and deployment so that it can provide 5GAA with only part of the spectrum needed to develop C-V2X technologies. Because grant of the requested waiver would create a permanent impediment to DSRC deployment, the Commission should deny the petition and instead consider initiating notice of inquiry to consider all issues surrounding 4G/LTE and 5G V2X technologies.

IV. CELLULAR V2X IS A STEP BACKWARD FOR ITS

A. DSRC Is Mature Technology and C-V2X Is Not

While DSRC technology is fully tested and is beginning to be deployed, C-V2X technology is still in its initial stage of development and has not been proven in any significant field test. It is expected to take at least several more years until the technology

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[14] *See* Car 2 Car Communication Consortium, , "Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Automation Applications," available at https://www.car-2-car.org/fileadmin/documents/General_Documents/C2CCC_TR_2050_Spectrum_Needs.pdf. *See also* Ensemble, "Using ITS G5 for efficient truck platooning," available at https://platooningensemble.eu/news/using-its-g5-for-efficient-truck-platooning5c1a203e7a226.

[15] SAE, "Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts J2945_201712," available at https://www.sae.org/standards/content/j2945_201712/.

[16] 5GAA Petition at 5.

is mature enough to be proven and be interoperable within the C-V2X set of manufacturers. As a result, real volume deployment is unlikely to happen before 2023.

In Annex A, appended to these comments, NXP highlights a number of shortcomings which have been identified in the first implementation version of C-V2X, LTE-V2X Rel-14.[17] While some of these deficiencies already have been published and corrected in the next version, Rel-15,[18] those corrections are not backwards compatible with Rel-14. In other words, the corrections are only applicable for future applications. Consequently, Rel-14 applications – including safety applications – cannot make use of the corrections. Moreover, some of the other known shortcomings are still in the process of being published and corrected, and thus will not be part of either Rel-14 or Rel-15.[19] Still other issues may not yet be known, due to lack of large-scale testing. A whitepaper by NXP and Autotalks provides additional analysis regarding the immaturity of C-V2X.[20]

Another illustration of the immaturity of C-V2X is the recent change from a 10 MHz channel configuration (as used in the test report in the waiver petition) to a 20 MHz

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[17] 3GPP LTE release 14 V2X refers to set of 3GPP 36 series technical specifications that define PC5 Sidelink V2X, amongst which 36.300 v14.8.0 http://www.3gpp.org/ftp//Specs/archive/36_series/36.300/36300-e80.zip provides the overall description, and where the full list of technical specifications can be found in RP161603: https://portal.3gpp.org/ngppapp/CreateTdoc.aspx?mode=view&contributionUid=RP-161603

[18] 3GPP release 15 V2X refers to set of 3GPP 36 series technical specifications that define PC5 Sidelink V2X, amongst which 36.300 v15.4.0 http://www.3gpp.org/ftp//Specs/archive/36_series/36.300/36300-f40.zip provides the overall description.

[19] "A First Investigation of Congestion Control for LTE-V2X Mode 4" ; Adel Mansouri, Vincent Martinez, Jérôme Härri, Jan 2019, http://www.eurecom.fr/fr/publication/5791/download/comsys-publi-5791.pdf

[20] NXP and Autotalks, "IEEE802.11p ahead of LTE-V2V for safety applications," available at https://www.nxp.com/docs/en/white-paper/ROADLINK-TECH-WP.pdf ("NXP and Autotalks Whitepaper").

channel configuration (as included in the actual waiver request).[21] The consequences of such a change are far from trivial. For example, the change requires a renewed consideration for the choice of actual LTE-V2X transmission parameter selection like the set of modulation and coding schemes, subchannel size and number of subcarriers. In addition, C-V2X in a 20 MHz channel configuration will suffer from amplified performance degradation due to the "near-far problem" and the "half duplex problem."[22] [23]

In contrast, DSRC technology already has undergone years of field, interoperability and conformance testing. U.S. plug tests by OmniAir and the European 'Plugtest™' by ETSI/Ertico (roughly yearly since 2011) have verified performance, interoperability between vendors and functionality. Projects with hundreds of cars using DSRC have been completed (e.g., large scale simTD already completed in 2013).[24] Deployment has started at locations worldwide. Cars are now available in the U.S. with DSRC systems pre-installed

[21] 5GAA Petition at 21 n.49.

[22] The near-far problem is amplified in a 20MHz channel because when twice the number stations transmit at the same time a larger variation of signal strengths is received by a receiver, which results in the impaired reception of more of the weakest. The half-duplex problem is amplified because twice the number of stations transmitting at the same time which will not be able to receive more of their peer transmissions.

[23] NXP and Autotalks Whitepaper.

[24] Safe and Intelligent Mobility - Test Field Germany, https://www.eict.de/en/projects/#project-19.

(e.g., select GM Cadillac models) and Volkswagen and Toyota have begun to offer cars with pre-installed DSRC systems in Europe and Asia.[25] [26] [27]

With tens of thousands of cars already equipped with DSRC systems, jurisdictions are investing in DSRC-equipped fleets and infrastructure. For example, in New York City, the city's department of transportation is deploying 8,000 vehicles (mainly buses) and hundreds of DSRC-enabled intersections. Most states also have announced commitments to invest in and deploy DSRC fleet vehicles and infrastructure.[28] Further, the U.S. DOT reports that by the end of 2018, there will have been more than 18,000 vehicles deployed with aftermarket DSRC-based V2X communications devices and more than 1,000 infrastructure V2X devices installed at intersections and along roadways in 25 states.[29]

B. 5GAA's C-V2X Performance Claims Are Unreliable and In Some Respects Are Misleading

5GAA's assertion that C-V2X has significant performance advantages when measured against DSRC is unreliable and to some extent misleading. 5GAA relies on its

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[25] Cadillac, "V2V Safety Technology Now Standard on Cadillac CTS Sedans," available at http://media.cadillac.com/media/us/en/cadillac/news.detail.html/content/Pages/news/us/en/2017/mar/0309-v2v.html.

[26] Volkswagen, "With the aim of increasing safety in road traffic, Volkswagen will enable vehicles to communicate with each other as from 2019," available at https://www.volkswagen-media-services.com/en/detailpage/-/detail/With-the-aim-of-increasing-safety-in-road-traffic-Volkswagen-willenable-vehicles-to-communicate-with-each-other-as-from-2019/view/5234247/6e1e015af7bda8f2a4b42b43d2dcc9b5?p_p_auth=oyU0Lqiz.

[27] Toyota and Lexus Announcement.

[28] John B. Kenney, Ph.D., "An Update on V2X in the United States: SIP-adus Workshop on Connected and Automated Systems," Nov. 13, 2018, available at http://en.sip-adus.go.jp/evt/workshop2018/file/new01_An_Update_on_V2X_in_the_United_States-Kenney-SIPadus-Nov.2018.pdf.

[29] Department of Transportation, *V2X Communications*, Notice of Request for Comments, Docket No. DOT-OST-2018-0210, available at https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/327941/usdot-v2x-rfc.pdf.

own whitepaper to underpin this claim of a 15 dB performance advantage. However, this document is demonstrably biased, and flawed in a number of aspects. In Annex A, NXP identifies the key elements on which the 15 dB performance advantage claim is based and explains why those assertions are unreliable and/or misleading. In Annex A, NXP also shows that a proper comparison suggests that DSRC has a 2.6 dB performance advantage over C-V2X. This means that 5GAA's claims of improved line of sight performance, enhanced reliability and superior resilience do not materialize.[30] C-V2X is not a superior technology to DSRC, but rather an incompatible and technically inferior alternative.

C. LTE-V2X Is a Temporary Solution that Should Not Be Permitted to Interfere with DSRC

The presently proposed version of C-V2X is LTE-V2X, which is based on legacy 4G LTE technology. As such, it is not 5G and it is not part of a roadmap to 5G using new radio technology. The move to 5G will need to be standardized and tested in dedicated spectrum. Moreover, cellular 5G V2X is not expected to be backwards compatible with 4G LTE, making any investment in or commitment to LTE C-V2X questionable. In contrast, DSRC IEEE 802.11p has a continuous roadmap, whereby the standard is extended for future use in a backwards interoperable way in the form of the IEEE 802.11bd standard definition (work in progress).

The 5GAA petition for waiver points to future developments of LTE-V2X into the 5G New Radio architecture as an argument in favor of the technical superiority of C-V2X.[31] 5GAA also speculates that massive MIMO and beamforming would be part of the 5G New

[30] *See* 5GAA petition at 3.

[31] *See supra* Section III.B.

Radio architecture thereby improving characteristics. However, 5GAA does explain how such a transition will happen and it does not address the impracticality of massive MIMO technology in V2V and many V2I applications, the expense of such technology in infrastructure roadside units (RSUs), or the undesirability of beamforming in any application requiring multicasting, as is typical for many V2V and I2V applications. 5GAA's suggestions of future enhancements are at this point purely speculative and should therefore not be relied upon by the Commission.

D. 5GAA Makes Unfounded Claims Regarding Additional Functionality

i. C-V2X's Claimed System Cost Advantages Ignore Reality

One of the arguments put forward by 5GAA as a benefit of using C-V2X technology is system cost reduction. However, an analysis of cost differences actually showed DSRC to be more cost effective.[32] For vehicles in production today, there will be no difference in additional system costs as between DSRC- and C-V2X-based vehicles since both are already fitted with both WiFi and LTE chipsets. Adding DSRC to a WiFi chipset costs about the same as adding C-V2X to an LTE chipset. Furthermore, there will be additional costs associated with these safety systems to cover automotive grade temperature, quality, and functional safety architectures which will be proportional to the complexity of the safety system they are embedded into. Automotive grade DSRC chips exist today and are less complex (and thus cheaper) than any future automotive grade C-V2X chips, which don't exist today and are not supported.

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[32] ABIresearch, "V2X System Cost Analysis: DSRC+LTE and C-V2X+LTE," available at https://unex.com.tw/public/uploads/shortcuts/ABI-DSRC-price-comparison.pdf.

In a scenario where cars have to incorporate both DSRC and C-V2X to ensure interoperability, V2X systems will become nearly twice as expensive as both technologies will need to be present to make sure communication is possible with all surrounding cars. In the future, presuming 5G C-V2X technology becomes available, the safety system will become even more expensive, as LTE and 5G V2X technology, which are not compatible with each other, will have to be added to maintain interoperability. There is no evidence that vehicle manufacturers and infrastructure owners are ready to absorb such cost increases to support ITS systems using multiple standards.

ii. C-V2X's Claimed V2N Advantage Is Illusory

The 5GAA petition, citing a report commissioned by 5GAA, suggests that V2N would bring substantial advantages to C-V2X by being able to offload traffic from the V2I and V2V communication unto the cellular network.[33] Four different reasons suggest that such claimed advantages are illusory. First, this type of offloading is unlikely to be applicable to the first wave of C-V2X (safety) applications at which the requested waiver is aimed, since these are highly dependent on multi-cast communication which is hard and inefficient to substitute with point-to-point cellphone networks connections.[34] Second, it would require paid-for connections with special service options in all cars, increasing costs for many, making traffic safety available only for more affluent parts of the population. Third, V2X communications in initial rollouts is very unlikely to cause overload in the first place due to the relatively limited bandwidth requirements of the first generation applications. Fourth,

[33] *See* Tom Rebbeck, et al., "Socio-Economic Benefits of Cellular V2X," at 28, Analysis Mason (Dec. 2017), available at http://5gaa.org/wp-content/uploads/2017/12/Final-report-for-5GAA-on-cellular-V2X-socio-economic-benefits-051217_FINAL.pdf.

[34] Defined in SAE J2945/1 as Electronic Emergency Brake Lights.

in case such C-V2X offloading to a cellphone connection is deemed useful, it can easily be applied on a completely equal basis to DSRC because the communication stack convergence between Uu (cellphone-mode) communication and V2X communication is in the higher layers of the OSI layering model: i.e., there is no specific functional integration between C-V2X and regular cellphone connectivity; complementary cellphone connectivity can be applied equally easily to DSRC.

iii. 5GAA's Arguments on Cost Efficiency Are Speculative and Invalid

5GAA asserts that cost efficiency advantages of C-V2X over DSRC can be gained by using existing mobile infrastructure. However different communication characteristics (short range communication at 5.9 GHz, requiring different antenna arrangements) makes this impractical; the coverage range of a cell tower is in this respect typically not compatible and a denser grid would be needed. Furthermore, it would be equally easy to incorporate DSRC functionality in the mobile infrastructure. Therefore, 5GAA's cost efficiency claims are unpersuasive.

5GAA also suggests that a mutual market acceleration will take place between 5G and C-V2X. This argument is purely speculative, if not doubtful for markets such as the U.S. and Europe where DSRC is the ITS standard adopted by regulators.[35] Further, there is every reason to expect that similar synergies can be attained through integration of DSRC and 5G functions.

[35] *See* European Commission, "Specifications for the provision of cooperative intelligent transport systems (C-ITS)," available at https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2017-2592333_en.

E. DSRC Market Development Is Happening at a Reasonable Pace

DSRC deployment is happening at a reasonable pace that reflects the automotive industry's 6-year design cycle for safety-critical systems. This design cycle is made up of contributions from the integrated circuit component manufacturer and from the car OEM as shown in Figure 1 below. In effect, there is typically a 6-year lead time in introducing new technology to a new production model. This can be even longer if the technology has an impact on a car's styling or its outward appearance, as may be the case with V2X when the technology requires roof or side mirror antennas.

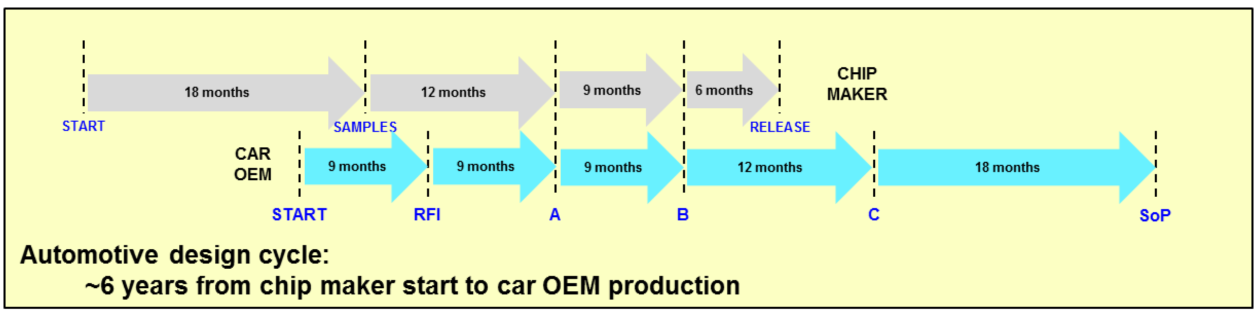

Figure 1

Although this 6-year lead time is often perceived as dead time, where the automotive industry is not moving forward, this is not the case. For example, NXP started development of the 1st-generation DSRC chipset in 2011, and GM subsequently committed to the technology and began pre-installing DSRC systems in its first Cadillac model in 2016.

It also is important to note that some U.S. car OEMs have been waiting for the completion of the NHSTA DSRC research trials which have lasted 10 years, and which will ensure the maturity of the technology and of the standards for safety applications. The trials will conclude with the successful operation of more than 32 smart city DSRC projects in 23 states across the U.S., with more than 10,000 vehicles and 5,000 RSUs deployed. The final pieces of the puzzle are now being finalized for a comprehensive roll-out in the U.S. in 2021, with the SCMS security architecture concluded and a test and certification body in place (Omniair). The 2021 roll-out will be jeopardized if a new, untried and untested standard is introduced in 2019, which might have the potential to interfere with the already deployed DSRC systems. Any change required by the chipset supplier and car OEM would push out more wide scale introduction of any life-saving ITS systems likely until 2025 or later.

Staying the course will be essential to the ability of the U.S. not only to lead but to keep pace with the rest of the word in ITS deployment and advances. In Europe, for example, Volkswagen is pushing ahead with deployment of DSRC technology across all models from 2019, safe with the knowledge that EU regulators have put in place legally-binding guiding principles for the introduction of any new technology after 2019:

- It should demonstrate technical maturity
- It should be interoperable
- It should maintain backward compatibility

Based on this stable regulatory landscape, European truck manufacturers will start deployment of DSRC technology to support truck platooning applications from 2021, providing additional fuel-saving opportunities for haulage companies on top of the existing safety applications. And like many U.S. states and smart cities, many European jurisdictions are moving forward with the deployment of DSRC-based roadside infrastructure. Austria, for example, has decided to deploy DSRC-based roadside infrastructure on a nationwide basis.

V. CONCLUSION

For all of the reasons explained herein and in the annexes appended hereto, NXP respectfully urges the Commission to deny the 5GAA request for waiver.

By:

/s/ Jennifer Wuamett
Jennifer Wuamett
Executive Vice President and General Counsel,
NXP Semiconductors

Lars Reger
Senior Vice President, Chief Technology Officer,
NXP Semiconductors

Peter Esser
Head of Government Affairs
NXP Semiconductors

NXP USA, Inc.
6501 William Cannon Drive West
Austin, Texas 78735
Direct: +1.202.621.1831
Email: peter.esser@nxp.com
www.nxp.com

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ANNEX A: SYSTEM PERFORMANCE ANALYSIS

I. On the 5GAA comparison between LTE-V2X and DSRC/IEEE 802.11p

Alessio Filippi, Vincent Martinez, Kees Moerman

A. Introduction

B. In October 2018, 5GAA (www.5gaa.org) published "V2X Functional and Performance Test Report; Test Procedure and Results" [1] in which the LTE-V2X technology promoted by 5GAA is compared against the DSRC technology, also known as IEEE 802.11p. Both technologies have been previously qualitatively compared in [2] and [3] as they aim to address the same set of applications in Cooperative Intelligent Traffic Systems (C-ITS).

In this document, we reproduced some of the results of [1] and show that, under the same operational conditions, DSRC has better performance than LTE-V2X Rel-14 mode 4. This is not in line with the conclusions of 5GAA [1].

C. Test set up

Among the multiple tests described in [1], we consider the lab tests described in chapter 7 of [1]. They are the most reproducible due to the controlled environment and provide a clear indication of the real performance of the system in the field. We consider only the DSRC performance as we have no access to any LTE-V2X HW solution.

We choose the same parameters as in Table 3 of [1], reported below for convenience, but use our own DSRC validation board with NXP DSRC chipset to reproduce the results.

Table 3: Common Parameters

Configuration	DSRC	C-V2X (PC5 Mode 4)
Channel	Channel 172	5860 MHz (Channel 172)
Bandwidth	10 MHz	10 MHz
Modulation	QPSK ½ (6 Mbps burst rate)	QPSK 0.46 (MCS 5)
Application Used	Savari	Savari
Tx/Rx Configuration	1 Tx 2 Rx	1 Tx 2 Rx
Device Details	Savari MW1000	Qualcomm Roadrunner platform
HARQ	NA	Enabled
Tx Power	21 dBm	21 dBm
Packet Size	193 Bytes	193 Bytes (5 Sub-Channels)*

* Sub-Channel size = 5 RB

For GNSS, a signal drop from a rooftop antenna is used in all the lab tests.

Figure 1. Table 3 of [1] reports the common parameters selected by 5GAA for comparing DSRC with LTE-V2X (aka C-V2X).

D. Results

The overall results are shown in Figure 2 and clearly indicates that the DSRC has better performance than LTE-V2X.

Figure 2 reports the PER percentage as a function of the overall path loss in dB. With a lower path loss, there is no error in the receive packets, but as the path loss increases, and therefore the received signal power decreases, the receiver will observe an increased number of wrongly decoded packets. The multiple PER curves should be mainly compared at a PER of 10%, as most of the C-ITS safety applications require a PER lower than 10% to work properly.

The orange and blue curves, 5GAA_ DSRC and 5GAA_LTE_V2X respectively, are taken from Figure 15 in [1] and reported here for convenience of comparison. The green curves indicate the results of our own measurements. The first green curve on the left (NXP_DSRC) is obtained by replicating the same lab test described in [1]. The curve is 7 dB more to the left as compared to the DSRC reference provided by 5GAA and proves that 5GAA chose a DSRC system with poor performance as compared to other existing and available DSRC systems. The better results come as no surprise as they are in line with the other standard DSRC products as, for instance, the CohdaWireless MK5 module [5].

In the following we explain the reasoning behind the multiple improvement steps of the DSRC solution that prove that DSRC is better than LTE-V2X.

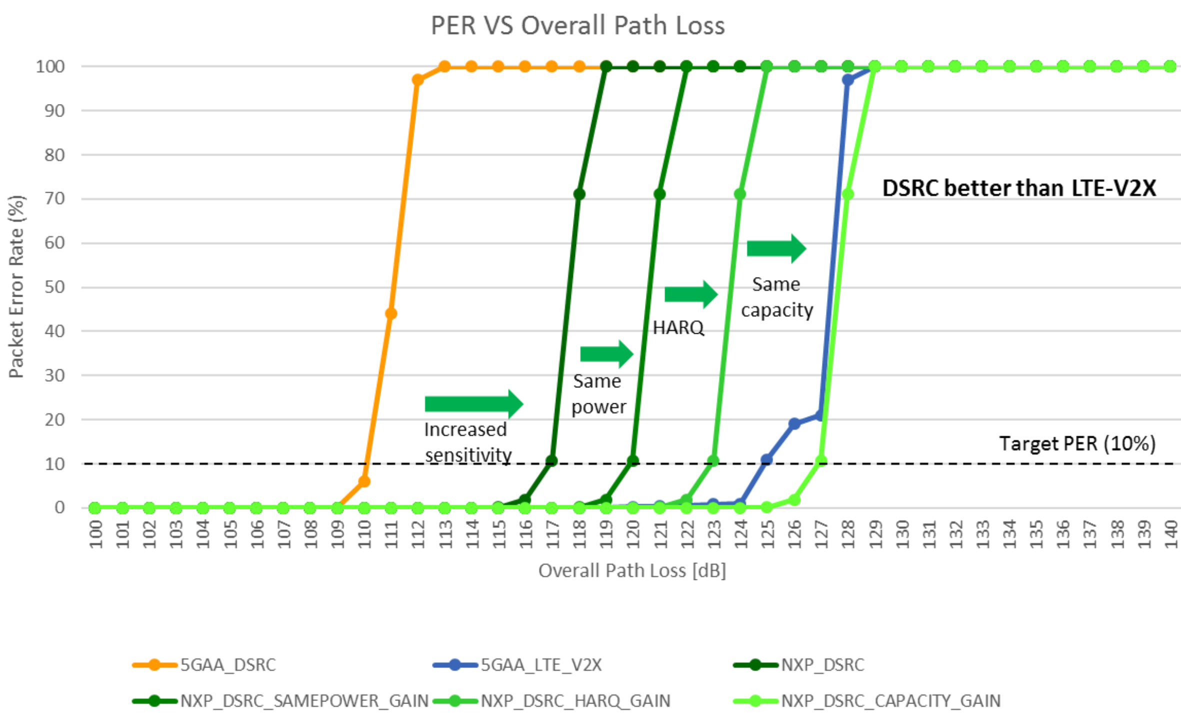

Figure 2. PER vs Overall path loss. The 5GAA results (5GAA_ DSRC and 5GAA_LTE_V2X) are taken from [1], Figure 15. The green curves are obtained by NXP. From left to right, the first green curve (NXP_DSRC) is derived by replicating the same test as described in [1] for DSRC with our own DSRC validation board. We can observe an increase in sensitivity of 7dB as expected for standard DSRC products [5, Table 2]. The second curve (NXP_DSRC_SAMEPOWER_GAIN) graphically depicts the 3dB gain of the DSRC when transmitting at the same power as LTE-V2X. The third curve (NXP_DSRC_HARQ_GAIN) assumes that DSRC has a similar HARQ mechanism implemented which could be obtained by doubling the transmission rate of the messages. Finally, the fourth curve (NXP_DSRC_CAPACITY_GAIN) includes the gain DSRC has if LTE-V2X would have a similar spectral efficiency. It should be further noted that the curves should be compared at around the 10% Packet Error Rate.

1. **Increased sensitivity: 7 dB**
   As mentioned above, the first green curve in Figure 2 (NXP_DSRC) represents the lab sensitivity tests with our own DSRC evaluation board [5] which has a much better sensitivity than the DSRC used for benchmarking in [1]. The performance is in line with standard DSRC products, e.g. [5].
2. **Same transmit power: 3 dB**
   The second green curve in Figure 2 (NXP_DSRC_SAMEPOWER_GAIN) represent the DSRC performance if it were using the same transmit power as LTE-V2X.
   As a matter of fact, in the comparison published in [1], the LTE-V2X is transmitting at twice the power of DSRC, which corresponds to a 3dB gain in the sensitivity measurements. The doubling in transmitted power is due to the choice of LTE-V2X parameters. LTE-V2X selected five subchannels each of five resource blocks to allocate the message size of 193 bytes, see Figure 1. Therefore, the single user uses about half of the available subcarriers to transmit the message while leaving the other subcarriers empty. At the same time, [1] assumes the same average Power Spectral Density (PSD) in DSRC and LTE-V2X which implies that the latter is transmitting at about twice the effective power, as graphically illustrated in Figure 3. It should also be noticed that the current regulations [4] define the maximum output power as of 23 dBm/MHz. Therefore, LTE-V2X would not even be allowed to transmit at higher power on half of the bandwidth, when transmitting at the maximum power.

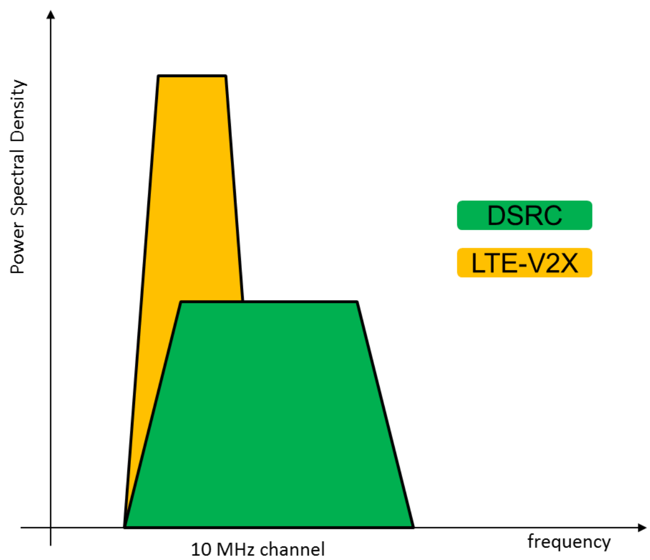

Figure 3. Illustrative example in the difference in transmit power mask between DSRC and LTE-V2X with the selected LTE-V2X parameters. A single DSRC user transmits on the entire 10 MHz band. A single LTE-V2X user, depending on the resource block allocation, transmits only on a part of the 10 MHz channel.

3. **HARQ retransmission: 3 dB**
   The third green curve in Figure 2 (NXP_DSRC_HARQ_GAIN) represents the DSRC performance if it would also use a form of retransmission as LTE-V2X.
   In [1], LTE-V2X uses HARQ (Hybrid Automatic Repeat reQuest) in all the field and lab tests. HARQ retransmission allows to send twice the same message. While this is certainly a powerful technique to get to more robust transmissions, it decreases the channel capacity and it practically means that the maximum number of users supported by the channel is reduced by a factor two. Such a feature might be usable in lab-tests or very uncongested environments, but it is clearly not representative of real-life congested performance. For a fair comparison, HARQ should be disabled in the LTE-V2X performance measurements. Since HARQ provides approximately 3dB performance improvement to LTE-V2X, when disabled the DSRC curve can be shifted to the right by 3dB.

4. **Same capacity: 4 dB**
   The forth green curve in Figure 2 (NXP_DSRC_SAMECAPACITY_GAIN) represents the DSRC performance if it were using a similar channel capacity as LTE-V2X.
   5GAA set up an unfair use case for comparison as the two technologies use a different number of effective bits/s/Hz. As reported in Figure 1, 5GAA used the modulation and coding scheme 5 (MCS5: QPSK, 0.46) for LTE-V2X which means an effective data rate of 3 Mbps (1.5 Mbps per user with a maximum number for two users in the same frame). For DSRC, 5GAA used MCS2 of IEEE 802.11p (QPSK, 0.5) which means an effective data rate of about 4.5 Mbps (it's lower than 6 Mbps due to the preamble and AIFS overhead). For a fair comparison, LTE-V2X and DSRC should use a similar capacity, i.e., a similar number of effective bit per second per Hertz. If we do so, we need to select MCS7 for LTE-V2X which does provide the same capacity as DSRC at the cost of about 4 dB degradation in sensitivity [6].

E. Conclusions

In the 5GAA report [1], the performance of DSRC versus LTE-V2X was presented in a technically misleading way by selecting a DSRC device with poor sensitivity, and a set of parameters that favor LTE-V2X in an unfair manner. The true performance comparison of DSRC and LTE-V2X Rel-14 mode 4 actually shows a completely different reality where DSRC is 2 dB better than LTE-V2X at the target 10% PER.

F. References

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ANNEX B: SOME KNOWN DEFICIENCIES IN C-V2X 3GPP REL-14

A few key deficiencies in the 3GPP LTE-V2X standards maturity and future-readiness aspects have been identified:

1. LTE-V2X Rel-14 suffers severe deficiencies due to immaturity and being standardized in a rush.
    a. Channel-interleaver / rate-matching pattern problem due to a reuse of other LTE Uplink and Sidelink schemes, as explained in several 3GPP RAN1 contributions (3GPP contributions: NXP R1-1717046 and R1-1717096, Huawei R1‑1717003), impacting severely the performance of Sidelink data channel (PSSCH) in 28.3%3 of the RB / modulation coding scheme combinations (3GPP contribution Huawei R1‑1717003). Solution incompatible with Rel-15.
    b. Redesign of the transport block sizes table in Rel-15, with TBS scaling, due to Sidelink having at most 9 data symbols, compared to 12 in LTE Uplink. Solved in an incompatible way in Rel-15.
    c. LTE-V2X Rel-14 Mode-4 suffers from excessive latency, partially due to the latency selection window of 20-100 ms in the PHY. Some discussions are ongoing at 3GPP to reduce this window in Rel-15, which will be incompatible with Rel-14.
2. LTE-V2X waveform is adapted from pure cellular applications, and is not adequate for V2X ad hoc networks.

   a. The small subcarrier-spacing of 15 kHz, carried on from the cellular bands (typically in the 2 or 3 GHz region), is not suited to the 5.9 GHz band. This results in LTE-V2X being very sensitive to frequency offsets. In 5G NR, 3GPP is planning to "unlock" the subcarrier-spacing, making it configurable per deployment.
   b. Half-duplex & near-far problems: due to the multiple-users access scheme, users will miss the safety messages that were transmitted concurrently. This does not occur in ETSI ITS-G5, which is based on a "listen-before-talk" principle. In Rel-14, this effect is potentially mitigated by retransmission of the signal (HARQ), at the expense of halving the maximum number of cars. This problem is not yet solved in Rel-15, but only in 5G NR.
3. The more mature version is LTE-V2X Rel-15, which fixes a few critical issues, is incompatible with LTE-V2X Rel14.
   a. PSSCH data channel of LTE-V2X Rel-15 is not backwards compatible with Rel14 stations. One reason for this is a structural change in several parameters to correct the flaws as indicated in the previous points such as the channel interleaver & Transport Block scaling fixes.
   b. Other reasons include the improvements integrated in Rel-15 which are not backwards compatible with Rel-14 (such as 64-QAM modulation). As a result, a Rel-14 device will not be able to decode Rel-15.

c. Exact DCC schemes are yet to be defined and demonstrated in multi-companies' plugtests. In contrast, IEEE 802.11p-based ITS standards have been thoroughly tested for years in all roads conditions.

4. 5G NR will be fundamentally incompatible with LTE-V2X.

    a. 5G NR technology will likely not be backwards compatible with the LTE-V2X Rel-15 nor Rel-14 transmissions. 5G N5 Sidelink will likely be re-using encoding techniques from 5G NR, with changes such as subcarrier spacing flexibility, LDPC encoders, MIMO techniques.